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Analysis of Intra-body Communication Measurement in Biomedical Applications

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ABSTRACT- The main objective of the paper is to characterize the concept of intra-body communication that allows electric signal to flow through human body. Various experiments are performed in order to verify how it is influenced under different conditions. The methodology used for this purpose is galvanic coupling method. The model is been implemented on ARM processor to measure heart rate and temperature of the human body. Measurements are carried out analyzing various IBC parameters such as size of electrodes, distance between transmitter and receiver, different environment and grounding. Practical conclusions are obtained thus analyzing the IBC performance. The system gives better performance as the data is transmitted in the form of packets. This provides secure and enhanced communication as compared to the existing systems.

General Terms- Biomedical application, Intra-body communication, etc.

Keywords- Copper, Galvanic coupling, Electrodes, ARM 7.

1. INTRODUCTION

Today proper health and treatment is given major importance than anything in everyone's life. Various technologies are developed for monitoring purpose. The existing systems still uses wires and cables for monitoring the patients. For risk patients and the patients who require long term monitoring feel uneasy, uncomfortable and immovable. This complexity can be reduced by replacing wired technology with wireless technologies. For example WLAN, Bluetooth, active RFID, etc. These technologies cause the electromagnetic waves to be radiated into the environment and also cause maximum power consumption. Table I describes the comparison of various wireless technologies and intra-body communication. Sensors are also used for monitoring biological parameters. But in order to monitor various parameters like blood pressure, temperature, heart rate, etc. a large number of sensors are required which again increases the complexity [1].

Table 1 Characteristic data of wireless technologies.

Technology	WLAN	Bluetooth	Zig-bee	Active RFID	Intra-body Comm.
Frequency	2.4/5.1GHz	2.4GHz	868MHz	134kHz	<1MHz
Data rate	54 Mbit/s	723.1 Kbit/s	20 Kbit/s	128 bit/s	>64 Kbit/s
Transmission power	100 MW	10mW	1mW	<1mW	<1mW
Size	PC card	PCB module	PCB module	Pill	Band-Aid/Pill

A solution to all these problems has been found out and introduced a new concept of communication that involves human body as a medium of transmission of data. It allows electric signals to flow through human body. This technology is termed as intra-body communication. Major transfer of data takes place through body without any loss into the air. Low power signals are required thus reducing power consumption and also allow miniaturization of the system to be used as Band-Aids or implantable pills [1].

2. IBC METHODOLOGY

2.1 Capacitive coupling

In this method of capacitive coupling, a pair of electrodes is used at both the ends of transmitting and receiving side. When a signal is applied to the pair of electrodes at the transmitting end, it induces an electric field to the body. The signal passes through the body in the form of electric field. At the receiving end electrodes, the signal is detected as function of varying electric potential in the body. These electrodes are placed at various different distances on the body. Hence data is sent between transmitter and receiver by capacitive coupling the electrodes to the body. Here the ground is used as reference and helps to detect the variation of electric potential in the body. In this method human body acts as a medium of transmission of signal [7].

2.2 Galvanic coupling

In this method of galvanic coupling, electrodes are attached to the ends of transmitting as well as receiving side. The signal is applied differentially to the transmitting electrodes. This induces very minor current (mA) into the human body. The current chooses the least resistive and more conductive path to flow through the body. The current flows into the body tissues. The ionic fluid in the human body acts as the carrier of information. The signal is detected by the electrodes at the receiving end. In this method, the effect of ground is negligible. Hence the body acts as medium of transmission of signal [7].

2.2.1. Types of Electrodes

For the coupling of signal, electrodes are needed to be interfaced between the devices and the body surface. The electrodes must be chosen in such a way that it provides maximum impedance matching with the human body. If the subject belongs to dry skin, it being a poor conductor creates high impedance between electrode and the body. Hence the electrodes must be pre-gelled that moisten the skin and provides minimum skin impedance for any signal acquisition. Most commonly used electrodes are silver/silver chloride and copper. Silver Ag has higher electrical conductivity as compared to copper Cu which quickly corrodes if used for long period of time. Another important factor is the space used by the electrodes in direct contact with the surface of the body. In this prototype, copper is being used due to its easy availability and cheaper rates [4].

2.2.2. Human Safety

As signal propagates through human body, there is a danger of physical risk and electric shock. Firstly, the physical risk refers to the pain and discomfort due to immediate removal of pre-gelled electrodes. To avoid this, the hairs need to be removed off the skin. The amount of current induced calculates the intensity of electric shock through the body. The maximum current tolerable and harmless to the human body is 20mA. In the proposed prototype, the power supply used is 5-10 volts which induces current in the range 0-3mA [4].

2.3 Experimental Setup

Initially the resistance of the body was measured to be in Mega ohms. A dc 5V was applied using a power supply through a copper pad on one hand and the output was observed on CRO through copper pad on the other hand. A 3V dc was observed on the CRO. A 5V square wave pulses were applied using CRO by the same procedure using copper pad on one hand. On the other hand, comparator and amplifier were connected to reduce distortion and after preset adjustments 5V square pulses were observed on the CRO. Similarly, data say "ABCD" was transferred using 8051 microcontroller at 9600 bps to the copper pad via UART. The same data was observed on the other side on hyper terminal of PC. The setup is shown below in *Fig 1*.

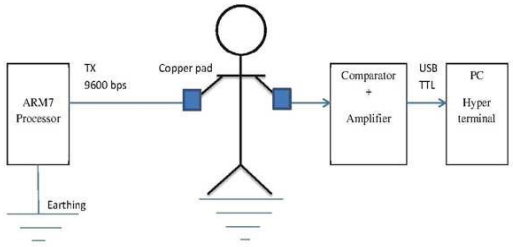

Figure 1. Experimental setup for data transfer

3. PROPOSED SYSTEM

Fig 2 shows the hardware architecture of the proposed system. It is mainly implemented on the ARM7 processor. The body temperature is sensed using LM35 temperature sensor. Heartbeat is sensed using light dependent resistor and LED. The signals are amplified and then compared with the reference using operational amplifier and comparator. This is referred to as conditioning circuit. The communication between slave and master devices is done through body. The coupling of the signal is done using copper pad through galvanic coupling method. LCD is to display patient's parameters i.e., temperature and heartbeat. The same data is sent via Bluetooth to the doctor's mobile in real time.

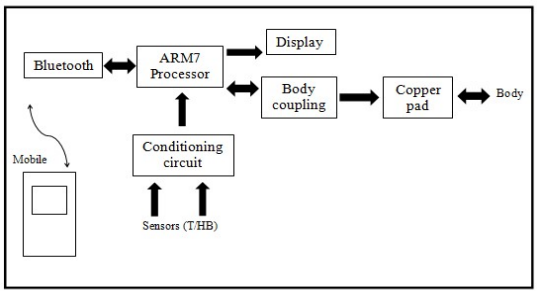

Figure 2. Hardware architecture of the proposed system

3.1 Format of the Packet

Fig 3 shows the format of the packet for transmission. The start of packet (start byte) is represented by MSB 2 bits. It can be either any constant or character (e.g. 'L', 'I'). The third bit indicates length of the packet (1byte). Fourth bit represents the type of data i.e. temperature or heartbeats (1- temperature and 2- heartbeat). The last bit indicates the value of the respective data. The device status or type of command is represented by the last two bits.

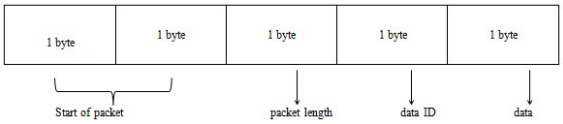

Figure 3. Format of the packet

3.2 Implementation

The proposed system consists of three devices namely heartbeat, temperature and wireless transceiver. These devices are differentiated as master and slave devices. Heartbeat and temperature devices act as slave devices and the wireless transceiver act as master device. These devices are attached to the body through copper patch. All these devices are implemented using ARM7 processor.

i. Slave device 1(Heartbeat module) - The heartbeat of the patient is sensed in the form of pulses using the heart beat sensor. The tip of the finger is inserted in the cavity that consists of light dependent resistor and LED to detect the pulses. If the pulses are found, the time delay between two pulses is calculated. The rate of heart beat is calculated as 60,000/pulse time (bits per minute). Here the pulse time is the average of five consecutive pulses. Amplification of the received data is accomplished using LM358 amplifier. This data is sent in the form of packet to the body via UART.

ii. Slave device 2(Temperature module)-The patient's temperature is sensed in the analog form using the LM35 temperature sensor. The analog data is converted to digital using ADC. The received data is amplified using LM358 amplifier. This data is sent in the form of packet to the body via UART. Calibration of data is done using the K factor as follows

$$K = (\text{Actual data}/\ \text{ADC raw data})$$

This value of K is multiplied to get the correct temperature in degree Celsius.

iii. Master device (Wireless transceiver)-The packets are received from the body via UART. The packet is decoded and again amplified to remove distortion and noise. The received data is distinguished by their ID byte in the packet. This device also consists of Bluetooth modem to transmit the data wirelessly to other Bluetooth devices like mobile phones etc.

iv. Mobile phone- Operating system being used is Android. Programming is carried out on eclipse platform in Java language using Android development toolkit (ADT).

4. RESULTS & DISCUSSION

Various experiments are performed to test the system's reliability under different conditions. The parameters chosen are different environment, distance between transmitter and receiver electrodes, different electrodes size and grounding. The reference used for comparison is thermometer and heart rate monitor.

A. Different environment- The parameters to be calculated i.e. temperature was measured on different days on different timing. The results concluded that the measurement of the parameters was not affected by the environment.

B. Different electrodes size- The copper used as electrodes in different sizes are attached to the body. The measurement was done under this condition. It was observed that proper the attachment of copper pad to the skin, maximum is the level of signal reception. Hence in medical monitoring systems, electrodes are preferred over copper pads.

C. Distance between transmitter and receiver electrodes- The communication between transmitter and receiver was measured placing the copper pads at different positions. As the distance increases, the speed of transmission of signal reduces in terms of baud rate. The results are demonstrated through graph of baud rate versus distance between electrodes as shown in *Fig 4*.

D. Grounding- The measurements are sensitive when the body touches the ground. The results are demonstrated through graph of percentage of successful transmission of data in various conditions as shown in *Fig 5*. The various conditions considered are fully isolated body, leg on ground, touch by other person, interference by mobile signals and interference due to power line.

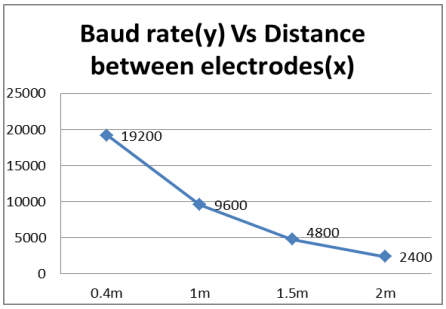

Figure 4. Graph of baud rate versus distance between electrodes

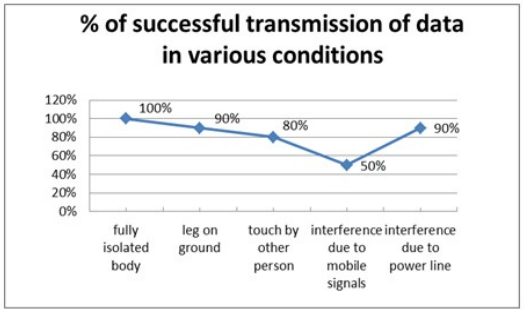

Figure 5. Graph of % of successful transmission of data in various conditions

5. PRACTICAL CONCLUSIONS

Table II: Analysis of Galvanic coupling in different conditions

PARAMETERS	GALVANIC COUPLING
Different environment	Not influenced
Different electrodes size	Bigger areas and proper adherence lead to better results
Distance between transmitter and receiver electrodes	Less the distance, faster the signal reception
Grounding	Less sensitive when body touched to ground

6. CONCLUSION & FUTURE SCOPE

This paper introduced a technology of intra-body communication and its application in biomedical field. It is proved that body can act as an electrical channel for transmission of data. Several wearable devices communicate through human body. The system performs data communication between a master device and slave devices. Temperature and heart rate parameters of the subject are monitored using this method. The prototype can be further miniaturized in the form of wristwatch and integrated with wearable devices or any other devices. This thus reduces the complexity of using wires and cables for monitoring patients. The Intra-Body Communication technique offers a more power efficient and also a secure short-range communication with less power consumption, compared to other wireless radio frequency technologies.

In future years, improvisation and advancement can be achieved in the various effects of motion of user on the quality of transmission, speed of transmission at different carriers and effect on health of the patient of long term treatment.

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